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BRITISH ANTARCTIC SURVEY



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NATURAL ENVIRONMENT RESEARCH COUNCIL

British Antarctic Survey

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THE BRITISH ANTARCTIC SURVEY, a component body of the Natural Environment Research Council, is responsible for British scientific activities in British Antarctic Territory and the Falkland Islands Dependencies. These territories comprise a total land area of about 700,000 square miles.

Most of the early expeditions to the region carried out important scientific work as well as geographical exploration, and much that they accomplished is still of value today.

British scientific programmes in the Antarctic have been almost continuous since 1925, having been interrupted only for 4 years during World War II. They were initiated by a Committee set up by the Colonial Office in 1917 to advise on Antarctic research. From this developed the Discovery Committee whose Discovery Investigations (now part of the Institute of Oceanographic Sciences, also a component body of the Natural Environment Research Council) carried out extensive oceanographical and biological research in the Antarctic, including the Antarctic Peninsula region, from 1925 to 1939 and in 1950-51. This was mainly in connection with the whaling industry and, since 1949, the Institute has acted as scientific adviser to the International Whaling Commission.

Another important forerunner of the British Antarctic Survey was the British Graham Land Expedition, 1934-37, which worked on the west coast of the Antarctic Peninsula. Notable among its achievements was the confirmation that Graham Land is part of the Antarctic Peninsula, not an island as previously reported, and the discovery of George VI Sound which was explored as far south as lat. 72°S.

The British Antarctic Survey owes much to

these predecessors, not least because some of their members helped to launch it in 1943 when it began as a war-time naval operation, "Tabarin", and it was they who immediately saw its scientific potential. Two bases were established at the beginning of 1944, and 16 more in the ensuing years, five of them being occupied at present by a total wintering party of 80 men. At the end of the war, control was transferred to the Colonial Office and the name changed to Falkland Islands Dependencies Survey, but links with the Royal Navy were retained, fruitful co-operation still being continued with the present ice-patrol ship HMS *Endurance*.

Scientific programmes were initiated at the beginning of Operation Tabarin, but for some years high priority had to be given to geographical exploration and mapping, and it was not until 1950 that a small office (the Falkland Islands Dependencies Scientific Bureau) was set up in London—under the directorship of Dr (now Sir) Vivian Fuchs—to organize these and publish the results. The programmes expanded rapidly in the next few years, largely as a result of the impetus given to Antarctic research by the International Geophysical Year (IGY), 1957-58, and close liaison was established with a number of British organizations interested in Antarctic science, notably the Scott Polar Research Institute, the Royal Society, the Meteorological Office, the Radio and Space Research Station (since renamed the Appleton Laboratory) and the Medical Research Council. At the same time, international co-operation was developed through the Royal Society and the Foreign Office. Part of the British contribution to the IGY was the Trans-Antarctic Expedition, 1955-58, which was organized and

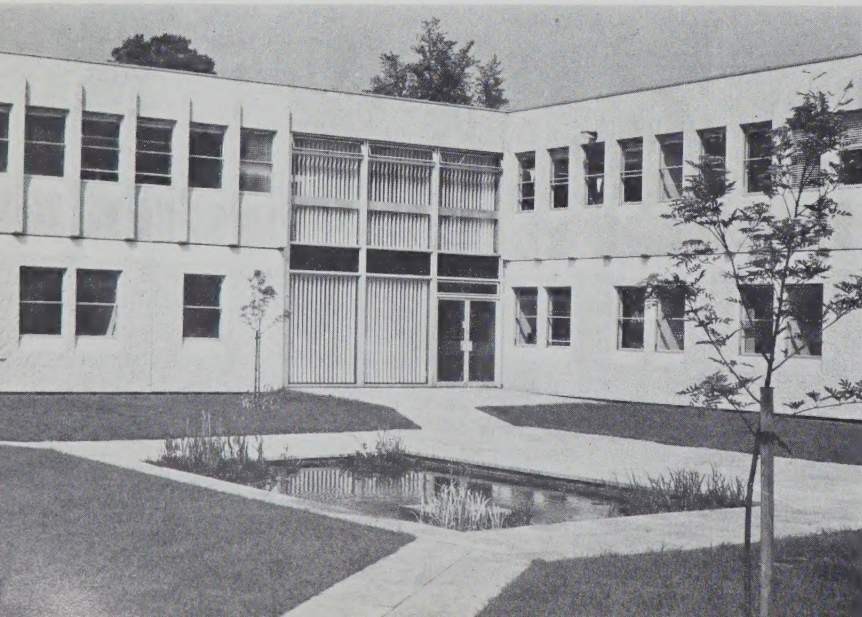
led by Dr Fuchs. The expedition succeeded in making the first overland crossing of the continent and carried out important scientific observations both at its base and *en route*.

By 1956, the increasing volume and complexity of the scientific work made it imperative to expand the scientific administration, but funds were limited and the only means of achieving this was to negotiate the setting up of units in appropriate university departments and research institutes. The first of these was established in 1956 by the Acting Director, Sir Raymond Priestley, at the University of Birmingham of which he had been Vice-Chancellor for 14 years, and others were subsequently set up in London, Edinburgh, Birmingham, Cambridge, Slough and Huntingdon. Special projects have also been

undertaken elsewhere. Although this was an important development and it was possible to enter into quinquennial agreements with the universities, the Survey's future was still uncertain.

The situation was changed, however, in 1959 when Britain became a signatory to the Antarctic Treaty. This Treaty was originally concluded between the 12 nations which had co-operated in the Antarctic so successfully during the IGY, and its aim was to ensure that the continent would be used for peaceful purposes only and that scientific investigation and co-operation could continue unhampered by politics, claims to territorial sovereignty being left in abeyance. As the Treaty was limited to the region south of lat. 60°S., the Antarctic part of the Falkland Islands Dependencies was re-designated British Antarctic Territory in 1962, and the name of the Survey changed to British Antarctic Survey. The advent of the Treaty increased the importance of the work being continued, especially as it had become apparent that the Survey occupied a key area in many world-wide fields of study and was also engaged in a number of projects of far-reaching significance. By that time, the programmes covered all major areas of environmental research, and it was a logical development that the British Antarctic Survey was granted more permanent status and incorporated into the Natural Environment Research Council in 1967.

All the scientific sections flourished but their wide dispersal had its disadvantages. The continued development of the Survey's science



The central courtyard of the British Antarctic Survey's building in Cambridge. The building was officially opened on 7 May 1976 by HRH The Duke of Edinburgh.

depended on the simultaneous development of the headquarters' activities—of personnel selection and logistics (the provision of everything required by the Antarctic bases, from matches to sophisticated scientific equipment, and the maintenance of ships and aircraft), the co-ordination of field programmes and the provision of central services. Moreover, as the work progressed, there was increasing overlap between the various disciplines. To ensure maximum efficiency, all these required maximum consultation and co-operation which could be achieved only by centralization, so it was hoped that all sections might eventually be housed together in one place in permanent accommodation.

This hope was finally realized when the new headquarters building was officially opened by HRH The Duke of Edinburgh on 7 May 1976. It had been specially designed and built for the Survey and is fully equipped with laboratories, workshops, a small library and a computer. It constitutes the greatest landmark in the Survey's history to date, and the Director and staff are confident that it opens up the way to further achievement.

Antarctic bases

The Survey maintains five permanent bases for field work in the Antarctic and these are manned throughout the year. There are also several minor bases used for summer operations and transit to the field. A number of field huts and refuges are available at strategic sites.

The base on South Georgia is situated at King Edward Point (lat. $54^{\circ}16'S.$, long. $36^{\circ}30'W.$); this was established as a main research station in 1969 following the collapse of the whaling industry. With a complement of up to 50 in the summer, this base is multidisciplinary; biological, ionospheric and meteorological studies predominate, while geological, geomorphological and glaciological field work was carried out by field parties supported by ships around the island. There are three small summer bases at Bird Island, Elsehul and Schlieper Bay, and these have complements of three or four men engaged in studying the abundant fur seals, albatrosses and other birds. An 8·3 m work boat is used for marine biology. This and other small craft also provide local transport.

The base at Signy Island (lat. $60^{\circ}43'S.$, long. $45^{\circ}36'W.$), one of the South Orkney Islands, was established in 1947, but the present main building of



The British Antarctic Survey's scientific station at King Edward Point, Cumberland East Bay, South Georgia.

prefabricated glass-fibre laminate was erected in 1964. Signy Island is biologically one of the richest places in the maritime Antarctic and the purpose of the base is to make intensive studies of the marine, terrestrial and fresh-water ecosystems. This base has a diving facility and much of the research into the marine and fresh-water environments is done by SCUBA diving, which involves working beneath the ice in winter. There is a 7 m launch for work at sea.

At the Argentine Islands (lat. $65^{\circ}15'S$, long. $64^{\circ}16'W$.) is the oldest operational British base in the Antarctic Peninsula. It was established in 1947 and is now known as Faraday base. It is situated on one of the islands forming a small archipelago about 5 km off the Graham Coast. The base complement varies from 11 to 15 and the main investigations are in the Atmospheric Sciences.



Rothera base at Rothera Point (lat. $67^{\circ}34'S$, long. $68^{\circ}07'W$.), Adelaide Island, occupies a rocky promontory on the south-eastern coast of the island. This has replaced Adelaide base 65 km to the south-west and is now the main base for summer air operations in the Marguerite Bay area and to the south. The aircraft use a snow runway 5 km from the base. The winter complement is 15 men and about 40 men operate from the base in the summer; parties are flown into the field to work on glaciology, geology and geophysics. There is a summer base at Fossil Bluff (lat. $71^{\circ}20'S$, long. $68^{\circ}17'W$.), Alexander Island, and this is used for summer field parties working on glaciology and aeromagnetic surveys.

There is also a small summer base at Damoy Point (lat. $64^{\circ}49'S$, long. $63^{\circ}30'W$.), Wiencke Island, which is an air facility and serves as a transit base for personnel disembarking from the ships before the break-up of the sea ice around Adelaide Island. The personnel are airlifted from Damoy Point south to Rothera.

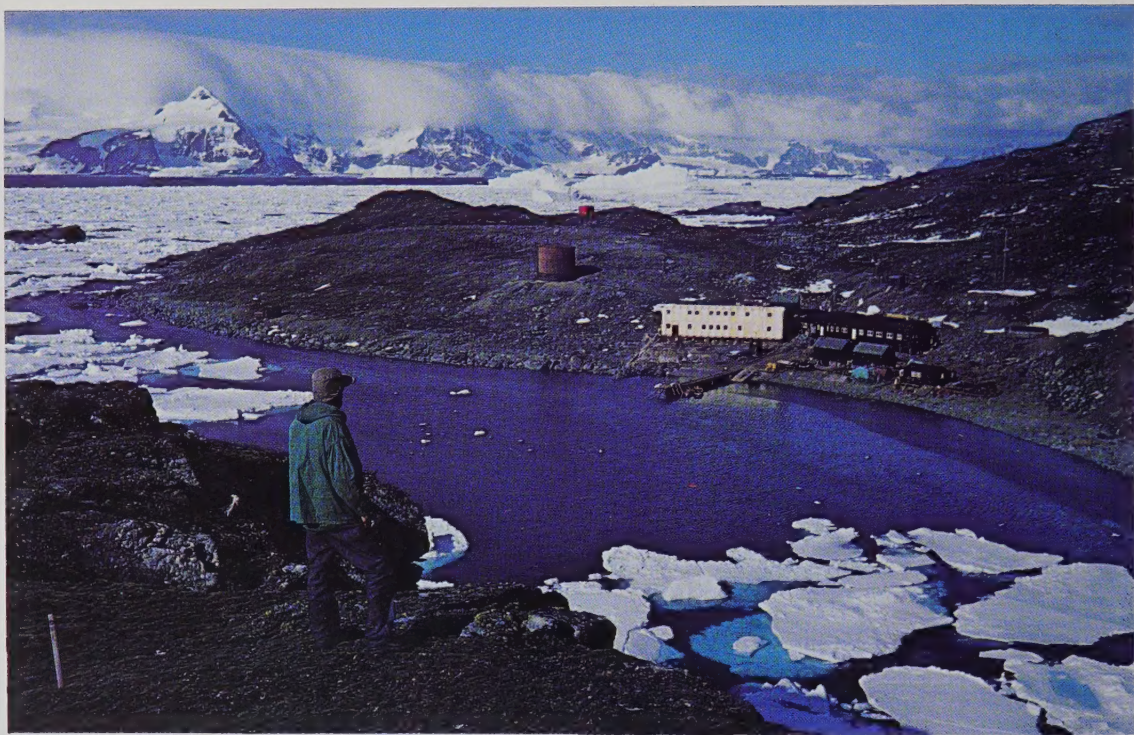
The most southerly base is situated at Halley Bay (lat. $75^{\circ}31'S$, long. $26^{\circ}50'W$.) on the floating Brunt Ice Shelf on the eastern coast of the Weddell Sea. Because the base buildings are constantly buried and crushed by accumulating snow, it has been rebuilt several times. The latest huts, constructed in 1973, were erected inside 6 m diameter steel tubes to avoid damage by the pressure from snow and ice. Access to the base is through shafts to the surface. The complement at Halley Bay is 15 men who are mainly involved in Atmospheric Sciences.

Ships and aircraft

The Survey operates two ice-strengthened ocean-going vessels for logistic support and research. RRS *John Biscoe*, 1,584 tons gross and 67 m overall, was launched in 1956. She has diesel-electric propulsion developing 1,450 shaft hp. The larger and



The British Antarctic Survey's Grytviken station, King Edward Point, South Georgia. Memorial cross to Sir Ernest Shackleton in foreground. Abandoned whaling station in background and administrative buildings in centre. (Photograph: J. W. H. Conroy/BAS.)



*The British Antarctic Survey's biological laboratory at Signy Island, South Orkney Islands.
Coronation Island in background. (Photograph: I. B. Collinge/BAS.)*



Left: The British Antarctic Survey's geophysical observatory at the Argentine Islands.

Top right: The newly built scientific station at Rothera Point, Adelaide Island.

Bottom right: The British Antarctic Survey's geophysical observatory at Halley Bay. The photograph was taken before the buildings were completely buried by snow accumulation.



RRS John Biscoe beset by fast ice off the west coast of the Antarctic Peninsula.

more modern RRS *Bransfield*, 4,816 tons gross and 100 m overall, was launched in 1970. Like *John Biscoe*, she is a diesel-electric vessel, developing 5,200 shaft hp. *Bransfield* is amongst the finest of the research vessels in the Southern Hemisphere. Both vessels are classed at Lloyds "100 A1* ice strengthened".



Two ski-wheeled de Havilland Twin Otter aircraft are operational in the Antarctic between November and March. They are used primarily for radio echosounding of ice depths, aeromagnetic surveys, topographical survey control, and the movement and supply of field parties. They also have a search-and-rescue function should this become necessary.

Organization

The British Antarctic Survey comprises an Administration Division which is responsible for co-ordination, logistics, staffing and finance, and three scientific divisions. Each scientific division is subdivided into about seven sections, including a leader, four or five contract scientists and two or three scientific assistants. The contract scientists are usually recent graduates, recruited for a period of about 5 years. In the case of the Atmospheric and Life Sciences, an initial training period in the United Kingdom is followed by 2½ years in the Antarctic and a further period up to 2 years in the United Kingdom completing the research for publication. For the earth scientists, summer field work in the Antarctic alternates with laboratory work in the United Kingdom and preparation for the next season.

Administration

The Administration Division of the Survey has a wider and more responsible task than that of most scientific organizations. In addition to the day-to-day administration associated with running a medium-sized research organization in the United Kingdom, there are the formidable logistic problems allied to controlling two ships, two aircraft and five permanent Antarctic bases.

The staff of the British Antarctic Survey is about 360; more than half of these are short-term contract workers, thus necessitating regular recruiting of staff. This task of recruiting staff for service in the Antarctic,

RRS Bransfield off Signy Island, South Orkney Islands.

where living conditions are arduous and physical stress may be extreme, requires far more careful and rigorous selection than for posts in more conventional locations. In 1977, the Establishments Section dealt with over 2,000 enquiries, held 200 interviews and recruited 70 staff, including scientists, cooks, builders, wireless operators, mechanics, medical officers, ships' officers and general assistants.

The Logistics Section organizes the provision of all material supplies, such as buildings, aircraft spares, vehicles and spares, fuels, food, sledges, tents, scientific equipment, radio equipment, clothing, chandlery, etc. When necessary, technical advice and assistance are obtained from outside organizations. In addition to its normal duties, the Administration Division deals with the ships' refits and provisioning. The

Survey's operations are on a large scale. For example, during the first 7 months of the 1976-77 financial year, 2,083 contracts were placed with 619 suppliers and these were subsequently followed through to packing and loading. Arrangements were made for the ships to be refitted in Southampton and the aircraft to be overhauled in Toronto. The ships sailed with approximately 14,500 separate pieces of cargo (*Bransfield* 11,800; *John Biscoe* 2,700) of 70 kg average weight. These included 1,500 crates processed by the packing stores, 7,500 crates delivered direct to the ships, 3,100 drums of fuel and lubricants, 1,300 sacks of coal, 14 vehicles, 150 tonnes of concrete mix, and one complete base building complex to house 35 men and weighing 120 tonnes. This new base, built at Rothera Point, was designed by our own projects team. *Bransfield* sailed with 770 tonnes of cargo and *John Biscoe* with 240 tonnes. For much of this cargo, specifications had to be discussed with suppliers, buildings designed, boats and vehicles modified, tenders sought, and bills of lading, customs and VAT documents, etc. prepared. In Southampton these cargoes are loaded by dock workers with all modern facilities, but in the Antarctic they have to be unloaded by the Survey's staff from ships lying offshore or alongside an ice shelf, using flubbers, scows or cargo sledges. At the most remote base at Halley Bay the cargo often has to be transported 2.5 km inland from the ice edge.

The Survey's two aircraft are overhauled each year at the de Havilland factory in Toronto. This involves a long ferry flight each way, including a 1,300 km crossing of Drake Passage. Excluding the ferry flight, each aircraft averages about 300 hr of flying each season.

Co-ordination and communication are vital tasks of the administration. The Antarctic base commanders and ships' masters are in regular contact with the Survey's headquarters in Cambridge by radio teleprinter, via the Cable and Wireless station



HMS Endurance in close pack ice off the west coast of Graham Land.

The radio-teleprinter equipment which provides the vital communications link between the Cambridge headquarters of the British Antarctic Survey and the Antarctic stations.

in the Falkland Islands. Over 200,000 teleprinter groups are transmitted each month. Action arising from these messages may involve not only one of the scientific divisions but also commercial suppliers, other research organizations, the Ministry of Defence, the Foreign and Commonwealth Office, or overseas institutions, such as the Division of Polar Programs in Washington.

The cost effectiveness of any scientific organization depends entirely on its scientific productivity and efficiency. The productivity of the Survey can be judged from the number of scientific papers which appear in international journals and those published in the *British Antarctic Survey Bulletin* and *Scientific Reports*. The Survey's efficiency is remarkably cost effective compared with that of other Antarctic organizations.



Atmospheric Sciences

The Atmospheric Sciences Division is primarily interested in the properties of the atmosphere, from the ground to its outer limits, and in relations between changes in it and solar activity. A very wide range of techniques is used in these studies, involving observations of surface and upper air meteorology, ozone, solar radiation, magnetic pulsations, diurnal change of the magnetic field, the ionosphere and magnetosphere. Thus the work of the Division is more interdisciplinary than is usual in scientific work and the results from the different experiments can be combined to solve problems which would otherwise be intractable.

The Survey's Atmospheric Sciences stations are strategically placed in a zone which forms a natural laboratory for the study of atmospheric phenomena; it is, in fact, unique. This occurs for two main reasons:



The logistics building at the Cambridge headquarters of the British Antarctic Survey. This provides a facility for the storage and packing of equipment essential to operations in the Antarctic.

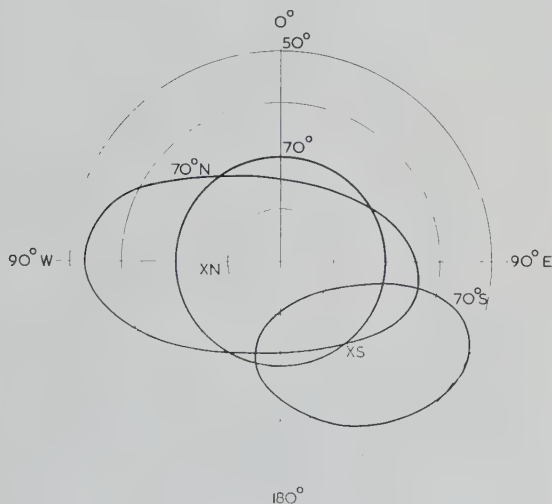


The British Antarctic Survey's geophysical observatory, Faraday station, at the Argentine Islands off the west coast of the Antarctic Peninsula. (Photograph: A. S. Rodger|BAS.)



*The British Antarctic Survey's Rothera station, Adelaide Island, under construction in 1976-77 summer. Mountains of southern Adelaide Island in background.
(Photograph: M. P. Landy|BAS.)*

- i. Antarctica forms a great dome centred near the south geographical pole which is almost entirely surrounded by water, providing a remarkably simple situation for studying the growth and decay of weather systems and their interaction with the higher atmosphere.
- ii. The magnetic field of the Earth corresponds to that of a triangular-shaped magnet offset from the centre of the Earth so that the south point pole is much further from the geographical pole than the line pole in the north (see diagram).



Polar projection map showing relative positions of geographical and magnetic dip poles and corresponding lines of magnetic and geographical latitude.

This has major effects on the behaviour of the high atmosphere, the ionosphere and magnetosphere, on the electric currents which flow in it and may have significant effects on the interaction between the atmosphere and the Sun.

In addition, the isolation of Antarctica from local sources of pollution gives special advantages for studies of the global transport of pollutants. The cold conditions, giving low water content in the atmosphere, and lack of dust, provide exceptionally favourable conditions for the measurements of the total ozone in the atmosphere and the incident radiation.

The Division has a high international reputation for the quality of its data. The unique geographical situation of the Survey's stations enables the data to be used for critical tests of theory. These advantages have played a significant part in the development of *F*-region wind theory and have contributed to a better understanding of phenomena due to particle precipitation and changes in the atmospheric composition.

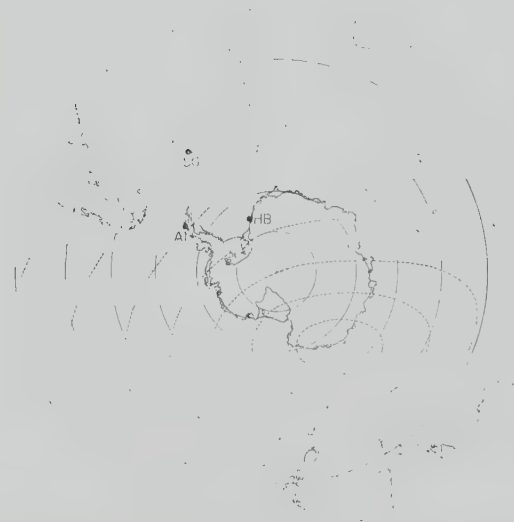
The wide areas of snow and ice give remarkably high and constant reflection of the Sun's light. This causes large changes in the brightness of clouds above an ice sheet relative to the same clouds above the sea (commonly known as "ice blink" and "water sky").

Marked differences in the behaviour of the stratosphere in the south relative to the north and the presence of highly reflecting snow surface makes it very important to calibrate all types of satellite atmospheric monitoring observations in this region. Experience has shown that unexpected phenomena can easily alter the interpretation of such measurements or generate correction factors which are quite significant. Thus, part of the work of the Division is both to calibrate and to use satellite observations. These are much more important than in the north since only a skeleton family of ground stations can be maintained in or near Antarctica and satellites must be used to fill the gaps and to provide the additional information needed to exploit the ground data. The Division also monitors man-made pollutants and, in particular, the fall-out of radioactivity from the atmosphere.

At low levels, the atmosphere is mainly stable with the gas pressure decreasing with height. Fluctuations in this system, which generate our weather and have

large effects on climate, are only a few per cent of the average pressure. As we move outwards, dynamic effects get larger and larger, and eventually completely control the shape of the atmosphere. At the greater heights, oxygen molecules are broken up to give atomic oxygen and ozone and eventually the oxygen-nitrogen atmosphere changes into a mainly hydrogen atmosphere.

The differences between magnetic latitudes and geographical latitudes are shown in the first diagram and the geographical situation is shown in the second diagram, which is a map of the Southern Hemisphere over lat. 30°S . with magnetic dip latitudes and the positions of the three main BAS Atmospheric Sciences stations.



Polar projection map of the Southern Hemisphere above lat. 30°S , showing the positions of BAS Atmospheric Sciences stations, magnetic dip latitudes and the simplicity of the land/ocean pattern. SG, South Georgia; AI, Argentine Islands; HB, Halley Bay.

At heights above about 65 km, ultra-violet and X-radiation from the Sun knock electrons out of the atoms of the air. The zones where detectable numbers of such free electrons can be detected are called the ionosphere and magnetosphere. The lower region can reflect radio waves and is thus important for long-distance high-frequency communication. At the greater heights, the air is highly ionized and its shape and movements are largely controlled by the magnetic field, hence the name magnetosphere.

At heights above about 32,000 km, the atmosphere no longer rotates with the Earth but is pushed out by particles coming from the Sun so as to form an enormous comet-like tail. This stretches well beyond the Moon's orbit. Thus the volume studied by the Division is very large.

A rapidly growing field of study is concerned with establishing whether weather and climate can be altered by changes in the radiation from the Sun during the solar cycle and, if so, the mechanism involved. Such interactions are likely to be due either to changes in its particle streams (the solar wind) or electro-magnetic radiation, or both. The geometry of the magnetic field provides critical tests of theories of such phenomena in Antarctica.

At present there is much interest in long-term changes in the ozone layer which could be sensitive to both solar and man-made perturbations. In particular, both solar protons and supersonic aircraft generate oxides of nitrogen which may destroy ozone. In the stratosphere the halocarbons from aerosols can also decompose to give active chlorine with similar results. The time constants are long so that, if present, such effects will probably take 5 years to be clearly evident, but once generated they will be significant for at least another 10 years. The results of carefully standardized sequences of ozone measurements over 16 years at Halley Bay and the Argentine Islands have been published and form a reference for detecting such changes in the future. Since the apparent seasonal changes vary with longitude, it is not possible to combine these with data from other stations. Initial comparisons throw some doubt on the accuracy of

satellite observations of ozone in the Southern Hemisphere.

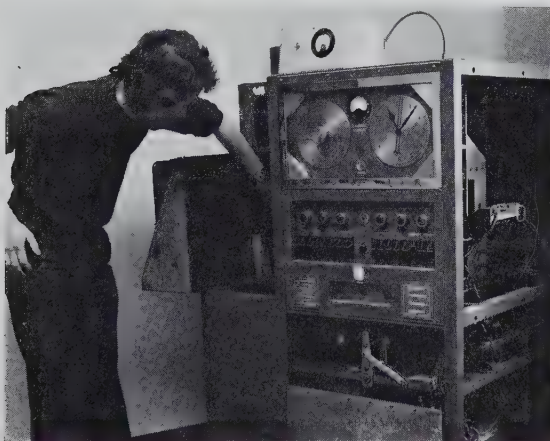
Systematic radiation measurements since the International Geophysical Year have provided data on the energy input due to solar radiation. One of the projects is the investigation of whether these changes show any links with general climatic variations. The data clearly show the influence of major volcanic eruptions which have varying effects on the available radiation when the surface has a high albedo (e.g. ice or snow) or low albedo (land or sea). Changes in the natural stratospheric aerosol content can also be measured. These produce different changes in radiation from those due to dust. The diffuse radiation changes rapidly across the edge of the ice fields and experiments are in progress to determine whether the effect on available radiation is significant.

The magnetic field geometry shown in the first two diagrams makes the *F*-region of the ionosphere abnormally sensitive to movements due to electric fields or winds. Thus the movements of the *F*-layer observed from the ground using an ionosonde can be used to study movements of the air in this region—between 160 and 480 km above the surface. The

fact that the auroral zone in this sector lies at very high geographical latitudes provides a unique opportunity for studying the relations between the ionosphere, troposphere and stratosphere.

The properties of the atmosphere at greater heights, the magnetosphere and its movements can be studied from the ground using whistlers and magnetic pulsations. The former are natural low-frequency radio signals in the audio bands generated by lightning flashes; the latter, with periods between tens of seconds and tens of minutes, are generated by turbulent movements in the magnetosphere. The sector where the BAS stations are located has special advantages for studying these phenomena, particularly during the southern winter, since the field lines from high geographical latitudes in the south terminate in the north at temperate latitudes. For example, the conjugate area to Halley Bay is Newfoundland, and to the Argentine Islands is not far from Washington. These areas have exceptionally intense thunderstorms during their local summers (southern winter) so that very large numbers of whistlers are generated. Lack of sun, due to the high geographical latitudes in winter in the south, minimizes the loss of signals in the ionosphere. The relatively simple configuration of the magnetic field in the south greatly helps the interpretation of the data.

Magnetic pulsations are an important tool for studying magnetospheric phenomena; the present experiments complement the major study of variation in magnetic pulsations with latitude in the United Kingdom, provide data for an important conjugate-point experiment between Halley Bay and Newfoundland, and link with ionospheric and VLF studies of phenomena near the plasmapause and some GEOS satellite observations.

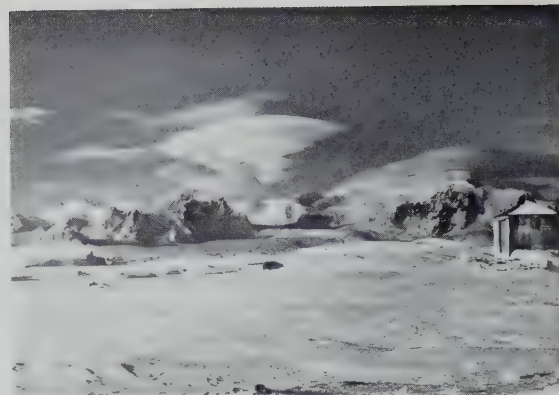


Training on an ionosonde at Cambridge. This instrument, a predecessor of radar, measures the density of free electrons present in the ionosphere and its variation with height. Although very old and still using valves, equipments of this type are unequalled for quality and quantity of data produced at high latitude.

Magnetic field observations have been carried out by the Survey for many years. An important scientific problem is the re-interpretation of quiet-day magnetic changes in terms of magnetospheric, ionospheric and polar current systems. The regular Universal Time variation in the horizontal field H , an increase at all Antarctic stations near 03.00–06.00 UT, appears near local midnight in our zone and is therefore particularly easy to identify and study. The Argentine Islands and South Georgia observatories provide data for the international K_s index in conjunction with five other southern stations. The high standard of data from Halley Bay and the Argentine Islands provides a firm basis for the quiet-day studies.

Most research in the Atmospheric Sciences is based on obtaining accurate measurements of atmospheric phenomena, taking advantage of the special conditions in the region and waiting for Nature to make the critical experiment. Occasionally, special experiments are added to the basic observations in order to test particular points. Thus the work is largely of a routine nature, preliminary sorting and analysis of the data being made at the Antarctic station. However, it is necessary for every man sent south to be a specialist in one field and to lend a hand in several other fields. This gives an exceptionally wide range of interest. In addition, of course, all members of an Antarctic station have to take part in the maintenance of the station and the work necessary to keep everyone fed, warm and entertained. It is usual for members of a station to take over each other's job for periods of a few days to occasionally 1–2 weeks so as to enable their colleagues to leave the station. At some stations such journeys are necessary for scientific purposes, e.g. at Halley Bay finding rate of movement of the station by the changes in the position relative to the local magnetic anomaly.

From time to time the Division organizes special experiments in conjunction with university groups or



other government departments, for example, during 1976–78 a high-frequency Doppler experiment to study movements of the F -layer and their relations with other phenomena has been deployed in the Antarctic Peninsula, involving the University of Leicester, the Instituto Antártico Argentino and the U.S. Division of Polar Programs, with financial support from the Science Research Council, and a VLF experiment to find the position and movements of ducts in the magnetosphere has been arranged with the University of Sheffield, again with Science Research Council financial support. There appear to have been abnormally large changes in climate during the last 60 years in the region studied by BAS and these are being investigated intensively. A collaboration on climatic problems has been arranged with the University of East Anglia. Magnetic observations at Halley Bay and South Georgia during the International Magnetospheric Study (IMS) period form part of both the national and international collaboration. For example, in conjunction with the Institute of Geological Sciences (IGS) and the University of London and University of York, both conjugate-point experiments between Halley Bay and Newfoundland, and relations between phenomena seen in the two hemispheres and their implication for theory are being studied.



Solar haloes and mock suns at the British Antarctic Survey's geophysical observatory, Halley station, Coats Land. In the centre are access shafts to two of the buildings, all of which are permanently buried by snow. (Photograph: H. J. Jones|BAS.)



One of the British Antarctic Survey's Twin Otter aircraft supplying geophysicists working at Sibelius Glacier, northern Alexander Island. (Photograph: R. G. B. Renner|BAS.)

The Division is responsible for developing electronic techniques for all BAS scientific work and has begun development work to this end. In particular, there is a need for new forms of sensors which can be operated at unmanned stations. The scientific work can be greatly extended with the aid of cheap unmanned stations, if such can be developed. This appears to be likely and some work on these lines is progressing as facilities allow.

The Division is responsible for organizing BAS computing and is at present the major user of the in-house PDP 11/40 computer. Much work is also carried out using the large computer at the Cambridge Computer Centre. At present the work falls into three classes: sorting, handling and interpreting large quantities of data; comparing data from different techniques with each other or with theory,

largely by statistical means; development of theoretical models using computer techniques. Most of the data obtained by the Division eventually appear in computer-compatible form.

Due to the unique situation of the BAS stations, many studies of the data are carried out outside BAS, in many cases in other countries, so that almost all of the data have to be widely circulated. The Division leads in international planning of future experiments throughout Antarctica and in some fields for the whole world. The Head of the Division is UK representative on the Upper Atmosphere Physics Working Group of the Scientific Committee on Antarctic Research (SCAR), and is Chairman of the Ionospheric Network Advisory Group (INAG) of the International Union of Radio Sciences (URSI), which is responsible for ionospheric soundings throughout the world.

Earth Sciences

The work of this Division covers a wide range of research in geology, geophysics and glaciology. In selecting Earth Sciences research problems, it is important to assess whether or not it is more rewarding or more cost effective to attempt to solve a particular problem in the Antarctic rather than in a more accessible part of the world. Although scientific research was only one of the motives which led the Survey to commence work in the Antarctic Peninsula, this region has since been found to occupy a uniquely favourable position for certain studies of general and indeed global significance. Investigations thus far have provided an exploratory framework of base-line data on which future programmes and developments may be based.

The main purpose of research in the geological sciences is to understand the origin and evolution of the solid earth. Modern concepts of plate tectonics emphasize the need to integrate a wide range of



The head of the electronics laboratory, developing new electronic equipment at Cambridge.

geological and geophysical data and harness them to the solving of major problems. The most important problem in the Southern Hemisphere is to reconstruct the Gondwanaland supercontinent and investigate the manner and timing of its fragmentation over the past 200 Ma or so. At present, the position of Antarctica with respect to South America and Africa in the Gondwanaland reconstruction, and the relationship between the two regions of Antarctica, are both relatively poorly understood.

The Antarctic Peninsula is clearly a key region for examining the relationship between South America and Antarctica; current field, petrological and geochemical work, aided by palaeo-stratigraphical work and radiometric dating, is leading towards a synthesis of geological events in this region over the past 200 Ma.



This region is fortunate in containing the only fossiliferous marine rocks of Mesozoic age in the whole of Antarctica and is thus well placed for studies of the changes in marine faunas at a time when Gondwanaland was breaking up and new seaways were being formed in the Southern Hemisphere. The region is rich in new species and offers great scope for the palaeontologist; even today, new fossil faunas are still being discovered. Rich fossil floras indicate that much of the region was forested from the Mesozoic until Upper Tertiary times, and show that glaciation commenced later in the Antarctic Peninsula than on mainland Antarctica. A major programme on Alexander Island is providing valuable data on the history of the Pacific margin of Gondwanaland, and work in the Shackleton Range with its anomalous structural trend has a direct bearing on the relationship between the two regions of Antarctica. The Scotia arc, a loop-shaped submarine ridge with scattered islands connecting South America with Antarctica, is of major scientific interest. Individual fragments found around the arc, such as South Georgia and the South Orkney Islands, preserve evidence of the nature of the geological link between the two continents and of processes which have been operative during the past 200–300 Ma along this active plate boundary. This region offers a number of exciting research possibilities; current interest of BAS is focused on the anatomy and mode of development of a pre-Cretaceous marginal basin–island–arc system, which is uniquely well exposed on South Georgia. This investigation is wide-ranging and includes sedimentology, structural geology, geochemistry and radiometric dating.

All aspects of Antarctic research are dominated more by the ice environment than by any other factor. The vast Antarctic ice sheet, through its heat exchange with the ocean, influences conditions over the entire Earth. Antarctica provides the only contemporary example of an ice sheet in an extreme

One of the helicopters from HMS Endurance over the mountains of northern Marguerite Bay.

glacial period and it is the principal factor controlling sea-level round the coasts of Britain. By studying its form, flow and stability, it is possible to understand the causes and effects of former glaciations on other continents. The Antarctic ice sheet provides a unique area of deposition and preservation of atmospheric precipitation from the past. Dating techniques are used to establish variations in space and time, not only of the precipitation itself but also of the terrestrial and extra-terrestrial impurities within the ice, and these can be determined in an environment that is almost free from local contamination. While many of the physical properties of ice are best studied in the laboratory, an understanding of the deformation of large ice masses by gravity flow can only be obtained by theoretical studies coupled with careful measurements of processes on a continental scale.

The Survey's glaciological programmes have made important contributions to contemporary understanding of the physical properties of ice. By concen-

trating on the study of ice shelves, which are particularly well represented in British Antarctic Territory, fundamental advances have been made at relatively low cost compared with work on the inland ice sheet. Elsewhere, remote-sensing techniques are used to study the ice thickness, sub-surface glacier dynamics, bedrock morphology and the physical characteristics of the ice-rock interface. Radio echo-sounding, using a pulsed radar at a frequency to which ice is transparent, is the method employed by the Survey. In 1963, the British Antarctic Survey were the first to achieve the continuous recording of glacier thickness from a moving vehicle and in 1966 also the first to operate an airborne system in the Antarctic. The Survey's aircraft have since flown ice-sounding profiles over tracks totalling around 80,000 km. Results have included published maps giving the first information on ice thicknesses in the Antarctic Peninsula region and extensive data on subglacial morphology that is of wide interest to all the Earth Sciences. The Survey were the first in the world successfully to adapt an echo sounder for making a detailed ice-depth survey of a single valley glacier and first to measure the velocity at which a glacier more than 1,000 m thick slides over its bed. Many geographical discoveries have also been made while radio echo-sounding; these show that in some areas the most recently published maps are in error by more than 100 km.

A large proportion of the land area of Antarctica is buried beneath an ice sheet which is in some places more than 4 km thick and is surrounded by an ocean which is in some places more than 4 km deep. The Survey is now in a good position to develop techniques for understanding subglacial geology and to test resulting theories against the rock exposed in nunataks. All interpretations of subglacial geology should be subject to test, the ultimate test being the collection of specimens from the bedrock beneath



The mountains of southern South Georgia viewed from Cooper Island.

the ice sheet. Drills that can penetrate ice at rates of 100 m/d are now available, and it is hoped to obtain shallow and intermediate depth drills in connection with international co-operative programmes. The present plans are to work progressively from the Scotia arc through the Antarctic Peninsula to the Ronne and Filchner Ice Shelf areas where, by studying the juxtaposition of the Andean, Ellsworth and Ross orogenic belts, it should be possible to solve one of the most vital outstanding questions about the rotation of the Antarctic Peninsula during the break-up of Gondwanaland. The Survey possesses an impressive array of modern techniques: airborne magnetometry, airborne radio echo-sounding, satellite photogeology, gravity and magnetic surveys, electromagnetic studies of the ice-rock interface, subglacial geomorphology, isotope geochronology and palaeomagnetism, and these are supported by outside facilities for rock analysis.

Life Sciences

Systematically organized biological research is the youngest of the three scientific disciplines pursued

by the Survey. Although valuable research on seals and penguins was done in the early days of the Survey, it was not until 1961, when the biological programme started at Signy Island, that a systematic approach to investigating the Antarctic ecosystem was begun.

The Antarctic is a region of severe climatic conditions and great isolation. The Southern Ocean is characterized by a species-rich, highly productive ecosystem which contrasts sharply with the species-poor, relatively barren terrestrial and fresh-water ecosystems of the islands and continental landmass. Antarctic organisms have had to adapt themselves in order to survive in an environment approaching the limit for life. The Survey is studying these ecosystems to discover what organisms are present and which of these may be judged successful. The adaptations of successful organisms are investigated to reveal the means used to exploit the environment, and the system is analysed to obtain a quantitative understanding of the component plants and animals and the relationships between them and with their environment. Such an understanding of the relatively simple Antarctic ecosystem will be of value in interpreting more complex systems elsewhere in the world.

Current biological research is concentrated at Signy Island and at South Georgia. Both of these islands offer a variety of communities for study and afford a contrast between the maritime Antarctic (Signy Island) and the sub-Antarctic (South Georgia). Though not used regularly for biological research, other bases provide a polar transect extending over 17° of latitude, including the Scotia Ridge, a dispersal route from South America.

Much of the original research has been concerned with the description and classification of the plants and animals. Without a proper knowledge of the organisms involved, it is not possible to progress to ecological studies and hence, in contrast to similar research in the United Kingdom and other developed



One of the heavily crevassed and seracated valley glaciers of South Georgia.



The British Antarctic Survey's ship RRS John Biscoe in pack ice off the west coast of the Antarctic Peninsula. (Photograph: BAS.)



The British Antarctic Survey's ship RRS Bransfield in fast ice at Signy Island, South Orkney Islands. (Photograph: I. B. Collinge/BAS.)

A bull elephant seal displaying to another bull on a beach at South Georgia.

areas, there is an initial taxonomic phase in nearly all projects. For most groups this is now complete and studies have progressed to more sophisticated ecological research. This is based on year-round observations so that seasonal changes, especially those associated with the harsher winter conditions, can be studied. The advantages of this approach are obvious but few other groups working in the Antarctic have been able to exploit it.

Between 1960 and 1973 botanical surveys and collections of plants were made throughout the maritime Antarctic and South Georgia. From these, descriptive floras together with ecological and phytosociological accounts have been produced. Since 1967 research has concentrated on selected ecosystems on Signy Island and South Georgia. Long-term study sites have been set up to investigate



the energetics of the moss-dominated ecosystems which predominate throughout most of the maritime Antarctic. Detailed comparisons have been made of the animals occurring there, and the role of energetics of bacteria and fungi in decomposition is being studied at the sites. At South Georgia, productivity studies of plants have revealed that production is often considerably greater than in similar communities in Arctic tundra. Experiments under controlled conditions have shown that Antarctic plants can photosynthesize well below 0°C and recover their activity rapidly even after being frozen. Detailed monitoring of micro-climates has revealed that, during much of the Antarctic summer, conditions for plant growth are much more favourable than ambient conditions suggest, with temperatures among vegetation exceeding 30°C at Signy Island or 40°C at South Georgia on calm sunny days.



Both of the British Antarctic Survey's de Havilland Twin Otter aircraft resupplying a field camp in the interior of Alexander Island.



The fresh-water bodies of the Antarctic represent the most limited ecosystems there and afford the simplest systems for analysis. Even the warmest lakes are frozen to depths of 1–2 m for 8–12 months of the year, but it has been shown that the light climate is the most important controlling factor. The phytoplankton is adapted to low light levels and has a peak activity in late winter when the lakes are still ice-covered. Activity falls with the thaw since the phytoplankton appear to be inhibited by high light intensities, but production is taken over by algae which form a mat on the littoral zone. In certain lakes the floor is covered with dense stands of moss even at depths below 15 m. During the winter, when light levels are very low, primary production appears to cease and the main activity is from bacteria and

Introduced reindeer which have adapted to the environment at South Georgia.

fungi. It has been found that light is controlled not by the ice cover, which is very translucent because the large ice crystals act as light pipes, but by snow which can reflect and absorb over 95 per cent of incident light. Snow cover varies from day to day, being controlled by strong winds and occasional brief thaws. The various plant communities can take advantage of both low and high light levels, thus maximizing production.

The Antarctic marine ecosystem offers the widest and potentially most profitable field for research. Early work, and commercial harvest, have revealed the degree of productivity of the seas and the need for intensive research is undisputed. The Survey's efforts have in the past been concentrated on near-shore waters, benthic systems and the land-breeding birds and seals that are accessible from the shore. Year-round observations have shown that in the near-shore system plankton production is concentrated in a very limited period of the summer, with small contributions from seaweeds and ice-associated algae. The high biomass of benthic invertebrates on the continental shelf continues into the sub-littoral as a fauna of burrowing molluscs, annelids and crustaceans, despite severe ice abrasion which restricts surface forms to sheltered habitats. The principal adaptations needed for survival in this environment have been studied. For most animals, this has involved adaptation to low but very stable temperatures, and adapting reproductive strategies or life histories to take advantage of the brief elevated summer production. A unique adaptation is the development of the "bloodless" condition in certain fish which lack haemoglobin or erythrocytes. Studies of the energetics of oxygen transport have shown that, in terms of work done, these fish, which rely on a large heart pumping low-viscosity blood through wide vessels at low pressures, can compete favourably with conventional fish in the cold oxygen-rich waters of the Antarctic. Studies on higher vertebrates have

One of the thicker moss banks on Signy Island, South Orkney Islands.



included the feeding relationships of birds which are locally important consumers, and the remarkable recovery of the Antarctic fur seal, which was almost exterminated by nineteenth-century sealers and now seems likely to approach its former abundance within the next 25 years.

The Survey is now developing a phase of open-ocean research. The seas in the Survey's area of operation are very rich in the small shrimp-like crustacean, krill (*Euphausia superba*). Krill is the key organism in the food-web that forms the basis of the ecology of the Southern Ocean. Increasing pressure on traditional fisheries, dwindling stocks and extension of exclusive fishing zones have combined to force nations with a distant-water fishing capability to look to new fields and resources. One of these is krill in the Southern Ocean. As yet, insufficient is known

A family group of southern fur seals on a beach at Bird Island, off South Georgia.

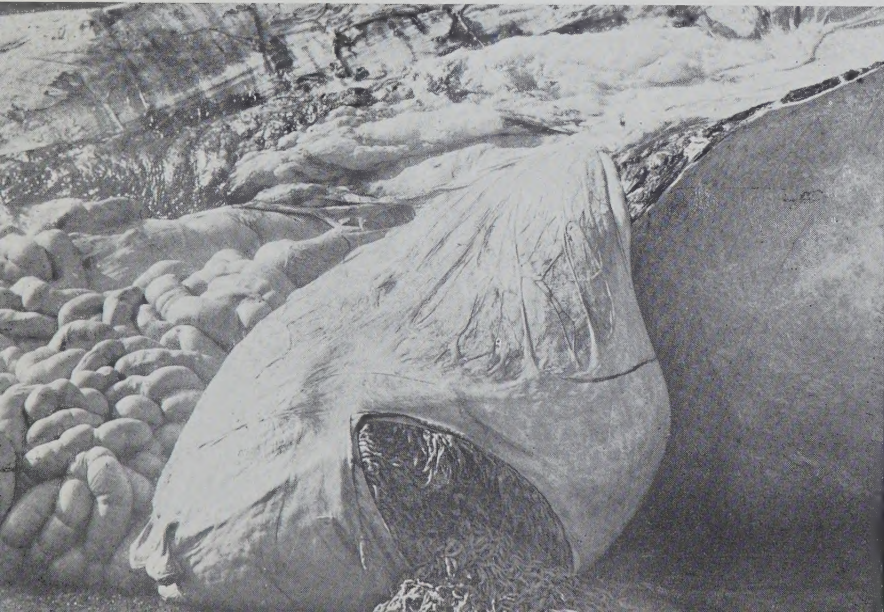


of the biology of krill and its principal predators to formulate sound management policies which will ensure that a krill fishery, when fully developed, will not have the same catastrophic effect as the

whaling industry. The British Antarctic Survey is ideally situated to carry out year-round studies at sea from its station on South Georgia. It is planned to gather information relating to the environment, biology and behaviour of krill which will enable us more fully to understand its role in the Antarctic marine ecosystem and, in particular, the balance between krill and those animals, like whales, seals and penguins, that are almost exclusively dependent on krill for food.

The Survey's medical officers usually undertake medical or physiological research programmes. Conditions at the Antarctic stations provide unique opportunities for studying "captive groups" in an extreme environment. Naturally, many of the research topics are related to the particular conditions of work in the Antarctic. Thus, studies of physiological adaptation to cold, cold diuresis, sub-clothing temperatures and protective clothing have been made. An interesting extension, relating to the growing

interest in environmental medicine in the North Sea oil industry, where many divers are employed, is the heat relation of wet-suit SCUBA divers in the Antarctic. At the Survey's most southerly station, Halley Bay, where light and dark are on a yearly rather than a daily alternation, a study has been made of sleep patterns. Because diet can be easily monitored at the Antarctic stations, research on topics such as levels of blood-lipids or vitamins, is facilitated. Small isolated groups have provided an ideal opportunity for research on the transmission of the common-cold virus.

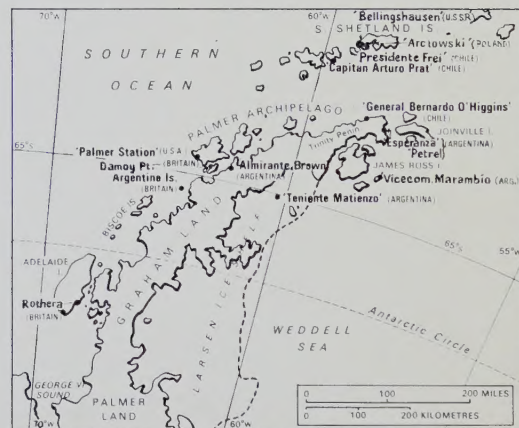


Krill (Euphausia superba) is the main diet of certain southern whales. This photograph shows the stomach of a whale distended with krill. (Photograph reproduced by courtesy of the Institute of Oceanographic Sciences.)



Map of Antarctica showing the locations of stations in use in 1977.

Map of the Antarctic Peninsula showing the locations of stations in use in 1977.



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Cover: Adélie penguins at Hope Bay, north-east Graham Land.